ULTRASOUND QUALITY INSPECTION OF AVIAN EGGS

Cross-Reference to Provisional Application(s)

This application claims the benefit of U.S. Provisional Application No. 60/269,281, filed February 16, 2001, which is incorporated herein in full by reference.

Background of the Invention

1. Field of the Invention.

The invention relates to non-invasive inspection of avian eggs to make a quality finding and, more particularly, using ultrasound inspection of avian eggs to make a quality finding such as fertility or viability or of other indicia of relative usability, and in consequence of the finding sorting the eggs in at least two and preferably three or more categories.

A number of additional features and objects will be apparent in connection with the following discussion of preferred embodiments and examples.

2. Prior Art.

It is known to use nuclear magnetic resonance imaging (MRI) of avian eggs to make a sex and possibly fertility determination. U.S. Patent No. 6,029,080 -- Reynnells et al. However the process of nuclear magnetic resonance imaging (MRI) of avian eggs to make a non-invasive determination of any kind will be beset with problems.

The MRI equipment requires a very high capital investment and has unproven reliability. The economics of egg producing operations do not allow purchase of a back up

system or expensive components in case of failures of the main system. The MRI equipment is stationed to catch eggs in transit during egg transfer operations. Egg transfer operations cannot be idled for even thirty (30) minutes or else thousands to tens of thousands of eggs will spoil.

The MRI image is in fact a virtually perfect slice of the egg through a given plane. However, the internal structures that allow a sex or fertility determination are hard to make out in such a perfect slice. Indeed U.S. patent of Reynnells et al. discloses quite distinctly how the egg must be oriented in a just so orientation, and then multiple images are taken on 0.5 mm spacings (ie., 50 slices per inch). After that, the best slice has to be determined because next, analysis requires finding a reference marker (eg., eyes or eye sockets) away from which origin a succeeding finding of the sex marker is paced.

Correspondingly, not only must an image from an optimum plane be obtained, the image must be analyzed for subtle features. Just as humans can be trained to develop the right "feel" for vent sexing poults, humans might develop an "instinct" for the when all the right combination of factors in a given MRI image suggest a given determination. But human analysis is unfeasible for lack of speed. Computers, though inherently speedy, lack instinct. Computers are far less reliable than humans at making determinations based on subtle factors. Harvard professor Stephen Jay Gould has quipped that to date "artificial intelligence" has yet to obtain merely the level of a cockroach.

It is reported that the MRI process requires cooling the eggs temporarily until the images are obtained. Eg., U.S. Pat. No. 6,029,080 -- Reynnells et al. Seasoned egg production workers are skeptical of that. Long custom has been to keep eggs in a carefully regulated environment of controlled warmth and humidity. Also, the nuclear MRI radiation just might be worrisome as a death ray to the germ of fresh eggs from the brood farm.

If egg production operations would consider adopting MRI techniques, they'd next have to face paying MRI certified operators at pay scales really unfamiliar in the egg production world.

In sum, the MRI process appears to be an ivory tower solution to a down and dirty problem. State of the art brood farms are known to produce a million (1,000,000) eggs a day. Yet margins are razor thin. The requirement for reliability in the methods relied on is paramount.

The investment in an MRI inspection process costs top dollar. Yet if the MRI inspection equipment goes out then the whole efficiency of the operation is impeded. If an MRI apparatus including its coil went down, it would simply have been cost prohibitive to own a back up in case of failures. There would be no reserve equipment to switch to or change out to in case of failures.

Given the foregoing seasoned veterans are skeptical of the feasibility of nuclear magnetic resonance imaging in poultry operations. The technology appears best left in hospitals where the throughput rate might be one to ten (1 to 10) patients an hour rather than millions of eggs a day.

Nevertheless, efficiency and optimization are paramount in poultry operations. Accordingly, poultry operations would benefit from any reasonably cost-justifiable method for culling poor unqualified eggs from the process stream at opportune times, such as during transfer from brood operations to hatchery operations.

What is needed is an improvement in culling unqualified eggs which overcomes the shortcomings of the prior art.

Summary of the Invention

It is an object of the invention to oscillate the shell of avian eggs to make a finding of shell quality.

It is another object of the invention to correlate the finding of shell quality to egg quality in terms of fertility or hatching or hatchling viability, or else in terms of any other usability criterion.

It is an additional object of the invention to oscillate the shell of avian eggs by means of acoustic energy.

It is an alternate object of the invention to oscillate the shell of avian eggs by means of a non-contact source of ultrasound.

It is a further object of the invention to detect such shell oscillations by means of a non-contact ultrasound transducer.

These and other aspects and objects are provided according to the invention in a method and apparatus for determining whether avian eggs are qualified or unqualified for a premium quality based on shell characteristics. The preferred method in accordance with the invention comprising the steps of providing a plurality of the eggs, oscillating the shell of each egg by a non-contacting source of ultrasonic waves to produce such a signal from the shell oscillation that is detectable by a non-contacting detector; and then determining whether the egg is qualified or not from analysis of the signal.

Preferably the detected signal is manipulated into a profile comprising detected signal strength versus time. This profile comprises an information portion that is analyzed for a positive indication of premium grade that is preferably characterized by at least one sufficiently steady and strong peak. The analysis of the detected more preferentially comprises integrated response (IR) analysis of the detected signal's strength versus time values.

Optionally, the profile's information portion is analyzed for either or both a positive indication of premium grade, which as before is characterized by at least one sufficiently

steady and strong peak, and/or a negative indication of premium grade that is characterized by relatively unsteady and weak signals across the width of the information portion.

In general, the positive indication of premium grade is correlatable to egg shell quality. In turn, egg shell quality is associated with a quality determination of the avian egg as a whole in terms of relating to fertility or hatching or hatchling viability.

The foregoing is advantageous for poultry and turkey farms having hatchery operations because the eggs sorted into the premium grade are graduated to hatchery operations. The other eggs are removed and either discarded or perhaps sorted for alternative other use such as pet consumption.

A number of additional features and objects will be apparent in connection with the following discussion of preferred embodiments and examples.

Brief Description of the Drawings

There are shown in the drawings certain exemplary embodiments of the invention as presently preferred. It should be understood that the invention is not limited to the embodiments disclosed as examples, and is capable of variation within the scope of the appended claims. In the drawings,

FIGURE 1 is a perspective view of an apparatus for ultrasound quality inspection of avian eggs in accordance with the invention, wherein a given egg is disposed between a source and a detector of ultrasonic energy, the detected signal obtained thereby allowing analysis to make such a quality finding as fertility, viability or other relative usability;

FIGURE 2 is an enlarged sectional view taken along line II-II in FIGURE 1 and which illustrates oscillations induced in the egg shell by the source transducer, wherein the distortion in the egg shell is illustrated on a gross scale for visual emphasis only;

FIGURE 3 is a graph obtainable from a display of a signal analyzer (eg., for processing the output of the detector of FIGURE 1), wherein the graph shows a profile of detected signal strength versus time for the special case of the source signal transiting across the gap to the detector without interposition of any object therebetween especially an egg (ie., therefore just through air), whereby the graph illustrates an example reference profile of detected signal strength versus time for such base factors as present air temperature and humidity as well as among various other things the distance of the gap between the transducers; such profiles in general consequently allowing analysis for such values as time-of-flight or velocity of the source signal, an integrated response of a selected peak or alternatively an integrated response across a selected bandwidth and so on;

FIGURE 4 is a comparable graph except showing an example profile for the representative case of a quality egg interposed between the source and detector, wherein even though the source signal's strength is diminished by greater than 99.9%, the information portion of the detected signal (ie., to the left of the gate) appears to ring strong and steady on at least one or two characteristic peaks;

FIGURE 5 is a graph comparable to FIGURE 4 except showing for contrast an illustrative case of an unqualified egg interposed between the source and detector, wherein not only is the source signal's strength diminished by greater than 99.9% but also the information portion of the detected signal (ie., to the left of the gate) is weaker and appears to clang unsteadily;

FIGURE 6 is a graph showing a profile of hatchlings lost (per 100,000 eggs) versus time based on data pertaining to turkey operations; and

FIGURE 7 is a block diagram flow chart of the method in accordance with the invention for providing ultrasound quality inspection and sorting of avian eggs, wherein the quality determination comprises any or fertility, viability or other usability.

Detailed Description of the Preferred Embodiments

FIGURE 1 shows an apparatus 54 for ultrasound quality inspection of avian eggs 51 in accordance with the invention, and as arranged in a preferred manner of operation.

The assumptions which underpin the inventive apparatus and method are, briefly, as follows. Ultrasonic energy is used to "ring" an egg 51 like a hammer tap rings a bell. The ringing egg is listened to. If the egg rings clear and strong in one or two or more characteristic modes of oscillation, the shell is reckoned as being of good quality. If not or, that is, if the egg clangs like an old metal platter dropped on the floor, the shell is reckoned as being of poor quality.

Importantly, the quality of the shell is reckoned as directly corresponding to the quality of hatchling viability. It is considered that poor shell quality is a symptom of various bad causes or bad indicators. To list a few, it is reckoned that poor shell quality indicates a cracked shell, or one compromised by micro-fractures, a porous shell, or an especially thin shell. Cracked, micro-fractured, porous and/or thin shells are unsuitable barriers to diseases and contaminants. It is known that poor shell quality allows diseases to enter and incubate inside the egg. These diseases like salmonella and mycoplasma spread from poult to poult when the bird emerges from the shell. Also, cracked, micro-fractured, porous and/or thin shells are unsuitable containers of moisture. Sometimes a bird hatches "pip alive" but dies in the struggle to get out of the shell or soon after. A frequent cause of this is weakness from dehydration.

More speculatively, it is also reckoned that poor shell quality could also be an indication if the blastoderm is already or nearly dead. The life of the blastoderm sustains the growing process of the egg as a whole including, presumptively, the health of the membrane lining the shell as well as even possibly the integrity of the shell in matters as absence of undue thinness or porosity and so on. Again, too much porosity is bad because the egg contents are then vulnerable to dehydration among other things.

To return to FIGURE 1, it shows a pair of non-contacting transducers 60 and 62 arranged in opposition to each other. Non-contact ultrasound is highly preferred so as to

avoid a liquid couple between the transducers and shell 64. It is feared that any liquid couple will cause intolerable problems. The non-contact probes do not subject the egg to any more harmful elements than already present in the controlled environment of brood, transfer and/or hatchery operations. The ultrasonic energy is transmitted from point to point. One transducer 60 serves as the source relative to its opposite number which serves as the detector 62. Example transducers suitable for the purpose include without limitation model nos. NCT 102 transducers of SecondWave Systems, Inc., State College, Pennsylvania, which transducers are characterized as nominally operating on a 200kHz frequency and having a planar 25mm active area diameter.

Not shown in FIGURE 1 (but indicated generally as portions of one or more blocks 54 and 55 in FIGURE 7) is a signal analyzer which is utilized for among other things processing the feed and detected signals of the source 60 and detector 62 respectively. An example non-contact ultrasound signal analyzer suitable for the purpose includes without limitation model no. NCA-1000-2En also of SecondWave Systems, Inc., State College, Pennsylvania. Given the foregoing, an egg 51 is disposed between the source 60 and detector 62 for an ultrasound quality inspection in accordance with the invention. Whereas the egg 51 is shown suspended by its pointed end from an inverted suction cup 66, the egg 51 could be supported in alternative other fashions without limitation.

FIGURE 1 shows the source transducer transmitting a beam of ultrasound energy that slams into one side (or the left side given the perspective of FIGURE 1) of the egg 51. In a typical arrangement with the above-identified transducers, the source and detector might be space 11 cm (4⅓ inches) apart. It is fairly well estimated that about 99.9% of the source energy is reflected by the egg shell 64 because of, in technical language, the mismatch between the acoustic impedance of air and the shell 64. On the opposite side (or right side given the perspective of FIGURE 1) of the egg, the detector 62 is listening for those components or portions of the source energy that reach it.

FIGURE 2 is a depiction for convenience of illustrative purposes only presumptively showing the dynamic oscillations induced in the shell 64 by the source signal. The egg shell

64 vibrates or oscillates somewhat as shown, although clearly not on such a gross scale as drawn, according to one or more characteristic modes of oscillation. See, eg., A.H. Benade, "Fundamentals of Musical Acoustics" (New York: Dover 1991). The shell 64 comprises a surface which is, needless to say, ovoid shaped. It will have modes of oscillations characteristic to transit around its "equator," or the hoop through which cutting line II-II is taken. In addition, the shell 64 surface will presumptively also have modes of oscillation characteristic to circumnavigation transit around its poles. FIGURE 2 provides illustrative depiction of wave energy transiting around the equator of the egg 51 as suspended in FIGURE 1.

FIGURES 3 through 5 are series of comparable views of graphs. Each graph shows a profile of detected signal strength versus time. FIGURE 3 shows a graph of a set-up test in the absence of an egg. FIGURE 4 shows one representative example profile of a good quality egg. FIGURE 5 shows one representative profile of an unqualified egg.

Preliminarily, the judgements of whether egg and/or egg shell quality is good or bad, or qualified or unqualified, were obtained through trials with actual eggs. Batches of eggs were inspected by the above-described non-contact ultrasound equipment and results were recorded. Some eggs were immediately broken open for examination of the contents including the blastoderm for such visual determinations as alive and healthy, deformed, dead or near death and so on. Other eggs were marked and tracked for observations through hatchery operations up to hatching, if that occurred, and then continuing on with the emerging poult for about six days after. The findings of that experience are graphically shown in part by FIGURE 6.

To turn to FIGURE 3, it is a graph obtainable from a display of the above-described signal analyzer. Generally the signal analyzer can be reckoned in many ways as PC computing system. The display comprises an attached monitor and the graphs shown in FIGURES 3 through 5 hereof are simulative of screen print-outs. The FIGURE 3 graph shows a profile of detected signal strength versus time for the special case of the source signal shooting across the gap to the detector without interruption by an object such as an

egg . The graph therefore illustrates an example reference profile of detected signal strength versus time for such set-up factors as the current air temperature and humidity as well as among various other things such as the distance of the gap between the transducers. This profile allows analysis of very basic values such as time-of-flight or velocity of the source signal and diminishment of the source signal across the gap.

FIGURE 4 shows a comparable profile except being a representative example of what is obtained for a quality or qualified egg. As matter of general interest, about 99.9% and more the source signal's strength is diminished. Much of the source signal's energy is reflected by the shell where the source signal originally slams into the left side of the egg (ie., left according to the perspective of FIGURE 1). That much which is detected by the detector produces a profile as shown by FIGURE 4 in the typical case of a quality or qualified egg. The twin peaks appearing in the information portion of the detected signal (ie., to the left of the gate) provide steady strong signals. In essence, the egg shell appears to ring strong and steady on at least one or two characteristic peaks. The portion of the profile to right of the gate is noise. It might comprise echos of the source signal as scattered about by the environment. The profile of FIGURE 4 permits various techniques of analysis including without limitation an integrated response analysis of one selected peak, or alternatively an integrated response across a selected bandwidth as encompassing two peaks and so on.

In contrast, FIGURE 5 shows an illustrative case of an unqualified egg. In FIGURE 5, the information portion of the detected signal (ie., to the left of the gate) is weak and unsteady all across the spectrum. At least one peak is apparent but it is unsteady and appears to dance on the screen. Indeed the peak dances left and right and might grow and recede in very quick time. Such a nub of a peak that dances so does not allow close integrated response analysis because the values are evidently too unsteady to average. One way to reckon the behavior of an unqualified egg is the detected signal appears to "clang" unsteadily and not ring true and strong, something akin to the clang of a cheap metal tray dropped on the floor.

FIGURE 6 as mentioned previously is a graph showing a profile of hatchlings lost (per 100,000 eggs) versus time based on data pertaining to turkey operations. Day 29 represents ordinary hatching time. Between day 0 and day 29 the profile has a bathtub shape. Presumptively the steeply dropping original part of the profile represents cases of dead, dying or deformed blastoderm due to matters present from the start. The steeply climbing part of the curve approaching day 29 is presumptively due to matters such as contaminated, diseased or dehydrated eggs. Days 28 through 30 might roughly correspond to "pip alive" deaths, or pips too weak to struggle out of the egg shell or terminally failing immediately thereafter. Days 31 through the end of the record generally correspond to hatchlings emerging dehydrated or diseased and otherwise too unhealthy too persist.

It is an aspect of the invention that problems with eggs and hatchlings through about day 35 (ie., the sixth or so day after expected hatching time) can be reasonably determined from an ultrasound quality inspection in accordance with the invention taken during the transfer operation between brood and hatchery operations, or on about day 0. Actual trials support this.

On the other hand, the non-contact ultrasound trials to date have failed to show any correlation between integrated response (IR) measurement and gender of live poults.

FIGURE 7 is a block diagram flow chart of a method 50 in accordance with the invention that utilizes ultrasound quality inspection of avian eggs.

Briefly, eggs are collected immediately as practicable at the brood farm after laying. Nowadays while the eggs are transferred from the brood farm to the hatchery they go through an intermediary process where they are washed and sterilized (not shown). The method 50 in accordance with the invention is preferably situated to operate on the eggs before the washing and sanitizing station. Hence in FIGURE 7, the eggs are collected and fed to a conveying apparatus 52 as known in the art. FIGURE 1 shows the eggs 51 transported in a suitable orientation and in a regular pattern or registry, both of which factors are desirable as more particularly described below.

Referring again to FIGURE 7, the eggs are conveyed to an ultrasound station 54. Ultrasound inspection transpires, the results of which are analyzed by an analyzer or processor. The analyzer is configured to make a finding as described above in connection with FIGURE 4 by means of an integrated response (IR) analysis of the steady peak or peaks of the information portion of the detected signal.

Generally speaking, in FIGURE 4 the first peak in time (eg., at ~ 222 μsec as distinguished from the peak at ~ 235 μsec)) has been discovered to most strongly correlate with egg shell quality. Hence the first peak in time might correspond to primary characteristic mode of oscillation whereas the second peak in time might correspond to a secondary mode, although to date this has not been established either way. Nevertheless, the IR analysis correlates one or more quality criterion(ia). The quality findings are preferably utilized for a process to make one of three choices:-- namely, that the egg is qualified for passing on through to the hatchery, or alternatively that the egg is not qualified for hatching but is otherwise gradable for other use such as pet food, or else that the egg is unusable and hence waste.

The quality findings obtained by the method 50 in accordance with the invention are shown by trials to correlate to various poor quality factors with egg shells, including things as cracks, micro-fractures, and undue porosity or thinness and so on. These same poor quality factors are also known to correlate to risk of contamination by, for example and without limitation, salmonella. Eggs at risk to salmonella contamination are unusable for any purpose and hence waste.

Returning to FIGURE 7, the eggs are sorted based on the findings of the ultrasound station by a sorter 56 which sorts each according to the corresponding finding. Sorting can be accomplished in accordance with various routine ways known in the art. Referring to FIGURE 1, the same inverted suction cup which lifts the egg for ultrasound inspection might also be utilized sorting duties. Alternatively, a successive inverted suction cup (not shown in FIGURE 1) might be utilized for this duty or else a carousel and so on. Persons ordinarily skilled in the art could readily devise routine other ways for doing so.

Whereas FIGURE 7 shows three dispositions for eggs this is done so merely for convenience in the drawings and the invention is not limited to sorting the eggs into any indefinite number of categories according to given criteria.

Yet in FIGURE 7, preferably the premium quality eggs are hatchery quality and this includes being of sufficient quality for human consumption. Correlation results show that such eggs are fertile and have the pre-requisite shell quality to hatch and provide a healthy hatchling through at least the first several days after emerging from the shell. Those eggs which fail the premium quality standards might next be considered if unusable. Unusable eggs are preferably discarded. However, if the egg has an intermediate quality, it remains fit for perhaps other use such as pet consumption and can be sorted for such.

In view of the foregoing, the results of the ultrasound inspection 54 are analyzed by an analyzer 54 or 55 or other information processor or controller 55 to make a finding correlatable to the egg's shell quality. The egg's shell quality in turn is correlatable to such grading factors as grading for fertility or hatching or hatchling viability. In more accurate language, the relationship between egg shell quality and indications of fertility or hatching or hatchling viability might be alternatively referred to as an association. The association between the egg's shell quality obtained from the detected signal of ultrasound apparatus 54 and the grading for fertility or hatching or hatchling viability is accomplished by pre-programmed routines and data stored on and executed by the information processor 55. Such routines and data would be based on the trials previously conducted as well as refined as time extends by further experience with the practice of the method and use of the apparatus 50 in accordance with the invention.

It is an aspect of the invention that the ultrasound inspection is preferably transacted as soon as the eggs are collected from the brood farm. That way, the grading or sorting decision is made as early as possible to extract out the sub-grade eggs before any more resources are expended on them. Accordingly the invention provides advantageous optimization of efficiency especially for high-volume poultry and turkey operation in which optimization and efficiency are paramount.

The invention having been disclosed in connection with the foregoing variations and examples, additional variations will now be apparent to persons skilled in the art. The invention is not intended to be limited to the variations specifically mentioned, and accordingly reference should be made to the appended claims rather than the foregoing discussion of preferred examples, to assess the scope of the invention in which exclusive rights are claimed.